CAMS Service Evolution

D5.4: Uncertainties in CAMS-GLOB-ANT emissions at the country and sector level

Due date of deliverable	December 31, 2024
Submission date	Jan 2025
File Name	CAMEO-D5-4-V2.2
Work Package /Task	T5.3.2: Uncertainty estimates of global anthropogenic emissions.
Organisation Responsible of Deliverable	CNRS
Author name(s)	Hugo Merly, Claire Granier
Revision number	V2.2
Status	Issued
Dissemination Level	Public

Funded by the European Union

The CAMEO project (grant agreement No 101082125) is funded by the European Union.
Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the Commission. Neither the European Union nor the granting authority can be held responsible for them.

1 Executive Summary

The goal of Task 5.3.2 of CAMEO is to quantify the range of uncertainties associated with the CAMS-GLOB-ANT global anthropogenic emissions. To meet these goals, two approaches have been followed:

- the development of a prototype of a web-based tool to calculate uncertainties, based on the uncertainties on emission factors. The tool has focused for now on NOx emissions for the transportation sector. The description of the tool and results obtained with this tool are shown in this report.

- uncertainties have also been estimated through the comparison of all publicly available inventories at the global and regional scales, for several countries and regions for NOx, CO, SO2 and OC. The calculation of the minimum and maximum values obtained from all the datasets providing emissions for different regions and countries has been performed, as well as of the ratio between the maximum and minimum values. This ratio can be used as an estimate of the uncertainty on the emissions. In the report, these ratios are shown for just a few countries: as the number of plots is very large, a link to a repository of all the results is given in the report.

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2 Introduction

2.1 Background

Monitoring the composition of the atmosphere is a key objective of the European Union's flagship Space programme Copernicus, with the Copernicus Atmosphere Monitoring Service (CAMS) providing free and continuous data and information on atmospheric composition.

The CAMS Service Evolution (CAMEO) project will enhance the quality and efficiency of the CAMS service and help CAMS to better respond to policy needs such as air pollution and greenhouse gases monitoring, the fulfilment of sustainable development goals, and sustainable and clean energy.

CAMEO will help prepare CAMS for the uptake of forthcoming satellite data, including Sentinel-4, -5 and 3MI, and advance the aerosol and trace gas data assimilation methods and inversion capacity of the global and regional CAMS production systems.

CAMEO will develop methods to provide uncertainty information about CAMS products, in particular for emissions, policy, solar radiation and deposition products in response to prominent requests from current CAMS users.

CAMEO will contribute to the medium- to long-term evolution of the CAMS production systems and products.

The transfer of developments from CAMEO into subsequent improvements of CAMS operational service elements is a main driver for the project and is the main pathway to impact for CAMEO.

The CAMEO consortium, led by ECMWF, the entity entrusted to operate CAMS, includes several CAMS partners thus allowing CAMEO developments to be carried out directly within the CAMS production systems and facilitating the transition of CAMEO results to future upgrades of the CAMS service.

This will maximise the impact and outcomes of CAMEO as it can make full use of the existing CAMS infrastructure for data sharing, data delivery and communication, thus supporting policymakers, business and citizens with enhanced atmospheric environmental information.

2.2 Scope of this deliverable

2.2.1 Objectives of this deliverable

The goal of Task 5.3.2 of CAMEO is to quantify the range of uncertainties associated with global anthropogenic emissions.

2.2.2 Work performed in this deliverable

The objectives of the deliverable have been met through two approaches

- The development of a prototype of a web-based tool to calculate uncertainties, based on the uncertainties on emission factors. The tool has focused for now on NOx emissions for the transportation sector. The description of the tool and results obtained with this tool are shown in this report.

- Uncertainties have also been estimated through the comparison of all publicly available inventories at the global and regional scales, for several countries and regions for NOx, CO, SO2 and OC. The calculation of the minimum and maximum

values obtained from all the datasets providing emissions for different regions and countries has been performed, as well as of the ratio between the maximum and minimum values. This ratio can be used as an estimate of the uncertainty on the emissions. In the report, these ratios are shown for just a few countries: as the number of plots is very large, a link to a repository of all the results is given in the report.

2.2.3 Countries and regions considered in the online tool and in the comparison of datasets

Data on emission factors and activity data are not available for all countries or regions. Therefore, we have grouped several countries into larger regions, and have applied the few data available for one country to all the countries in the same region.

We have used the 26 regions defined by the common Integrated Assessment Model (IAM) (https://www.iamcdocumentation.eu/IAMC_wiki), as these regions are used in the analysis of the emissions in several other projects, including CAMS. The definition of the countries and regions can be found at: https://www.iamcdocumentation.eu/Spatial_dimension_-_IMAGE.

A map of the regions is shown in Figure 1, and a detailed definition is given in Table 1 in Annex 1.

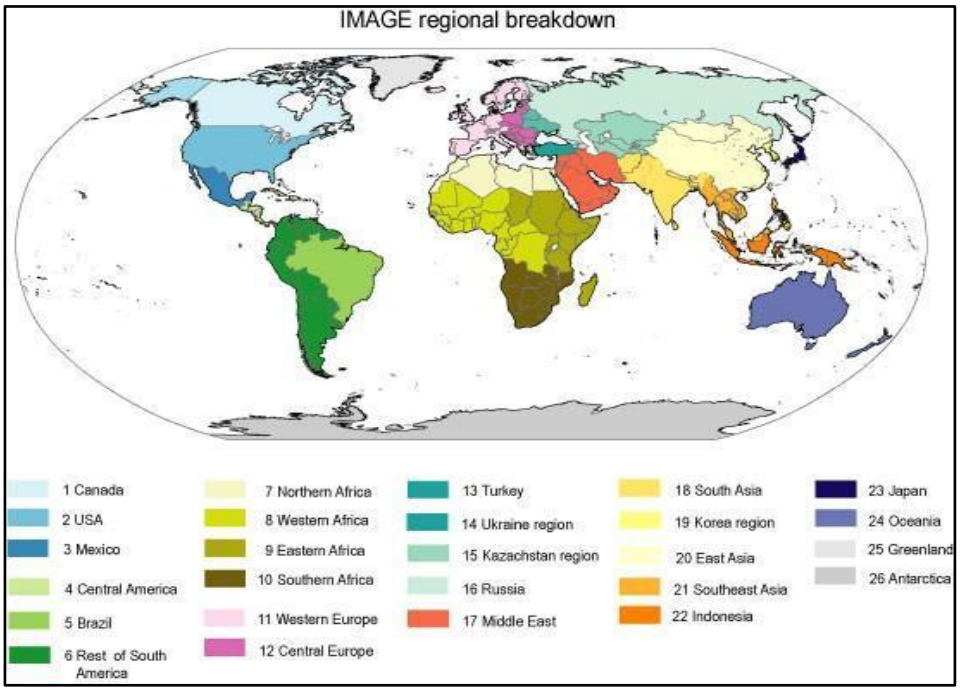

Figure 1: map of the 26 countries/regions used in the online tool and in the evaluation of the minimum/maximum values of the emissions

2.2.4 Deviations and counter measures

In the proposal, we planned to develop the online tool was supposed to be used for all sectors. However, due to the challenges in compiling and estimating emission factors uncertainty

information, the tool is for now limited to road transport NOx emissions, and uncertainties for other species have been derived using a different approach (intercomparisons of existing emission inventories).

2.2.5 CAMEO Project Partners

ECMWF	EUROPEAN CENTRE FOR MEDIUM-RANGE WEATHER FORECASTS
Met Norway	METEOROLOGISK INSTITUTT
BSC	BARCELONA SUPERCOMPUTING CENTER-CENTRO NACIONAL DE SUPERCOMPUTACION
KNMI	KONINKLIJK NEDERLANDS METEOROLOGISCH INSTITUUT-KNMi
SMHI	SVERIGES METEOROLOGISKA OCH HYDROLOGISKA INSTITUT
BIRA-IASB	INSTITUT ROYAL D'AERONOMIE SPATIALEDE BELGIQUE
HYGEOS	HYGEOS SARL
FMI	ILMATIETEEN LAITOS
DLR	DEUTSCHES ZENTRUM FUR LUFT - UND RAUMFAHRT EV
ARMINES	ASSOCIATION POUR LA RECHERCHE ET LE DEVELOPPEMENT DES METHODES ET PROCESSUS INDUSTRIELS
CNRS	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS
GRASP-SAS	GENERALIZED RETRIEVAL OF ATMOSPHERE AND SURFACE PROPERTIES EN ABREGE GRASP
CU	UNIVERZITA KARLOVA
CEA	COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES
MF	METEO-FRANCE
TNO	NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK TNO
INERIS	INSTITUT NATIONAL DE L ENVIRONNEMENT INDUSTRIEL ET DES RISQUES - INERIS
IOS-PIB	INSTYTUT OCHRONY SRODOWISKA - PANSTWOWY INSTYTUT BADAWCZY
FZJ	FORSCHUNGSZENTRUM JULICH GMBH
AU	AARHUS UNIVERSITET
ENEA	AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE

3 Prototype for an on-line tool for the calculation of emissions and their uncertainties

3.1 Methodology

We have developed a prototype website called **COCAU** (CAMEO Online Computation of Anthropogenic Emissions and Uncertainties). The goal of this tool is to compute and present, through interactive maps and diagrams, the values of emission factors and their associated uncertainties for each country and region mentioned in the previous section. Firstly, the emission factors have been sourced from publicly available inventories like IPCC, EPA, European Environment Agency, national statistics and published papers at country level. Secondly, the associated uncertainties have been calculated in most of the cases using Monte Carlo simulations and statistical analyses. This methodology is the most commonly used for aggregating emission factors and uncertainties. However, other approaches are also possible, as discussed in the poster of Doumbia et al., presented at the AGU conference in 2024 (https://agu.confex.com/agu/agu24/meetingapp.cgi/Paper/1661728). The Doumbia et al. study is not yet published and we have included a copy of the poster in Annex 2, at the end of the document. The values of the uncertainties used in the COCAU tool are available as an excel file, which can be found at: https://drive.google.com/file/d/1dcZljfZ0dLuetOyxynmpO7yXBY99BpoF/view?usp=drive_link. These data are also available on request and will be put in a public repository such as zenodo at the end of the project.

Currently, this prototype is designed to display, calculate, and download uncertainty values associated with NOx emissions from road transport. This sector is further divided into four sub-sectors:

- **Personal Cars (PC)**
- **Light-Duty Vehicles (LDV)**
- **Heavy-Duty Vehicles (HDV)**
- **Motorcycles (MOT)**

LDVs are represented by vans and pickups, while **HDVs** include buses, motor coaches, lorries, and road tractors.

3.2 Website development

The website of the prototype tool is publicly available at: https://eccad.sedoo.fr/cameo-wp5/. On the bottom part of the website, we have included the CAMEO and CAMS logos, together with the logos of CNRS and French AERIS (Atmosphere Data and Services Centre) organizations, which are hosting the website at no additional cost for the project.

This section describes the different features of the website. As shown in Figure 2, the website is divided into three main sections, each designed to guide users seamlessly through data selection, visualization, and exploration.

- First, the **main navigation** provides access to the primary features of the site through three available tabs:
  - **Map:** Displays an interactive map with emissions and uncertainty data by country and region.
  - **Graph:** Presents interactive charts for exploring the data in depth.
  - **Download:** Allows users to download selected data in various formats and offers a preview of the dataset.

- Secondly, the **selection panel** offers options to filter and customize the displayed data. Users can refine their selection through several filters:
    - *Parameters*: Choose whether to display emission factors or their associated uncertainties.
    - *Transportation Sectors*: Select a sector from HDV, LDV, MOT, PC, or All.
    - *Species*: Focus on a specific pollutant species (NOx).
    - *Regions*: Select regions to display on the map or in the graphs, corresponding to those introduced earlier (multiple selections are allowed).
    - *Countries*: Choose specific countries (multiple selections are allowed).

- Finally, the view area is the visual core of the website, where the selected data is represented as a map, graphs, or a download preview. Data can be grouped by country or region, depending on user needs.
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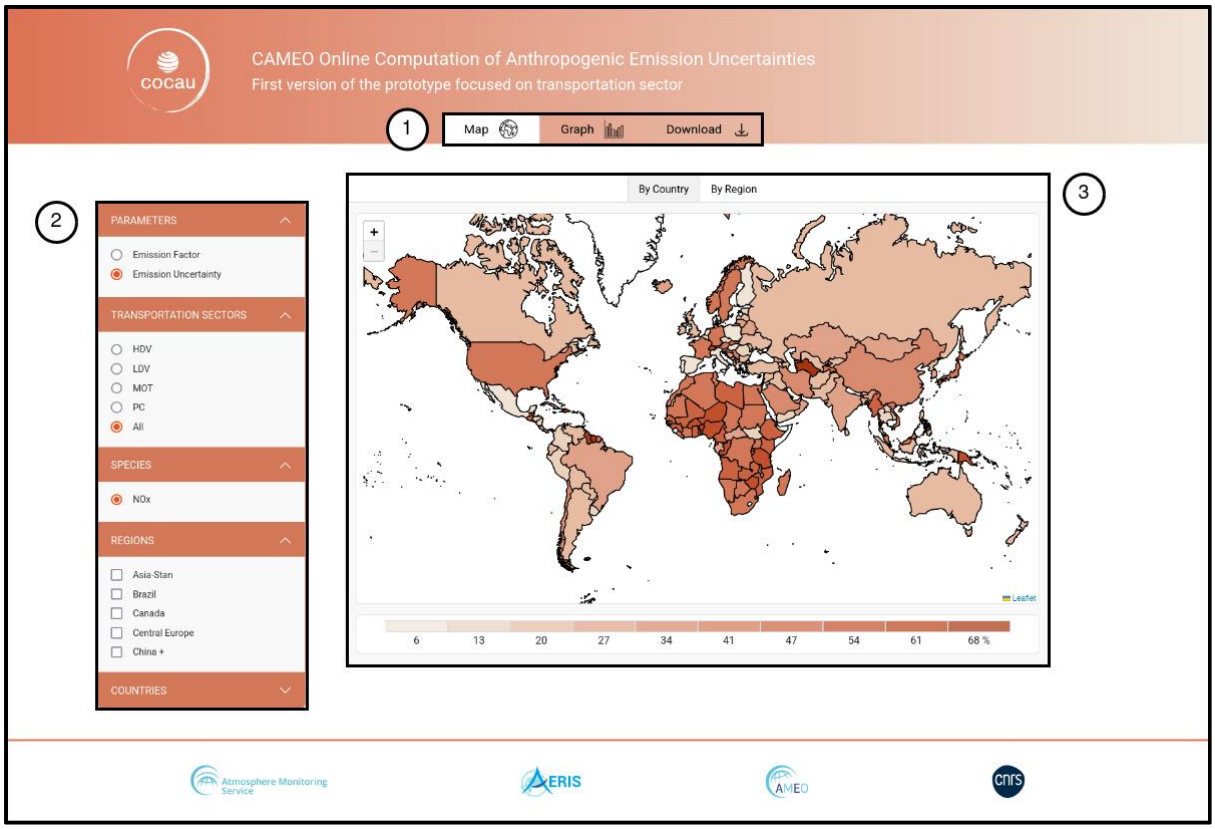


Figure 2: Overview of the main components of the prototype website

3.3 Website features

The website of the prototype tool offers three main functions, designed with a focus on viewing or downloading emission factors and uncertainties.

3.3.1 Map view

The **Map** component provides a highly interactive and visually engaging tool to explore emission factors and their associated uncertainties. Users can toggle between country-level and region-level groupings while analysing emission and uncertainty data to uncover trends and patterns at various scales.

As it is presented in Figure 3, the view item allows users to visualize four different combinations of data modes and grouping options:

- **Top-left:** Displays emission factors grouped by country.
- **Top-right:** Displays emission factors grouped by region.
- **Bottom-left:** Displays emission uncertainties grouped by country.
- **Bottom-right:** Displays emission uncertainties grouped by region.

Each map is equipped with an interactive colour scale at the bottom, enabling users to quickly interpret the intensity of the displayed data. The darker shades represent higher values (e.g., higher emission factors or uncertainties), while lighter shades indicate lower values.

The country grouping option provides a detailed breakdown, showing individual national data points, while the regional grouping aggregates data for specific geographical areas and calculates the associated regional average. This flexibility allows users to tailor their analysis according to their specific needs, whether they are looking for granular insights at the country level or broader trends at the regional scale.

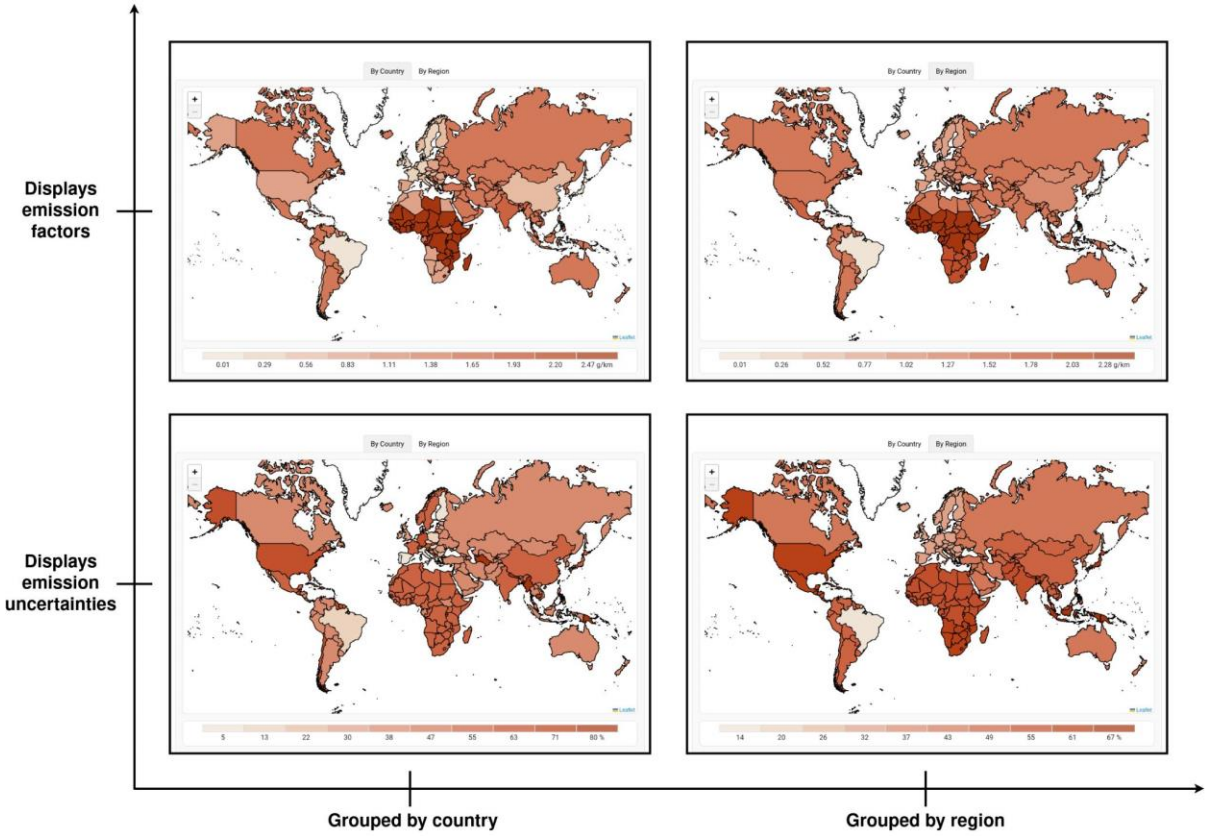


Figure 3 : Four visualization modes of emission data: emission factors (g/km) and uncertainties (%), grouped either by country or region for detailed analysis.

In addition, users can zoom in on the interactive map to take a closer look at emissions or uncertainty data at a more detailed level. As shown in Figure 4, the Map component provides two filtering options: filtering by regions (left) and filtering by individual countries (right).

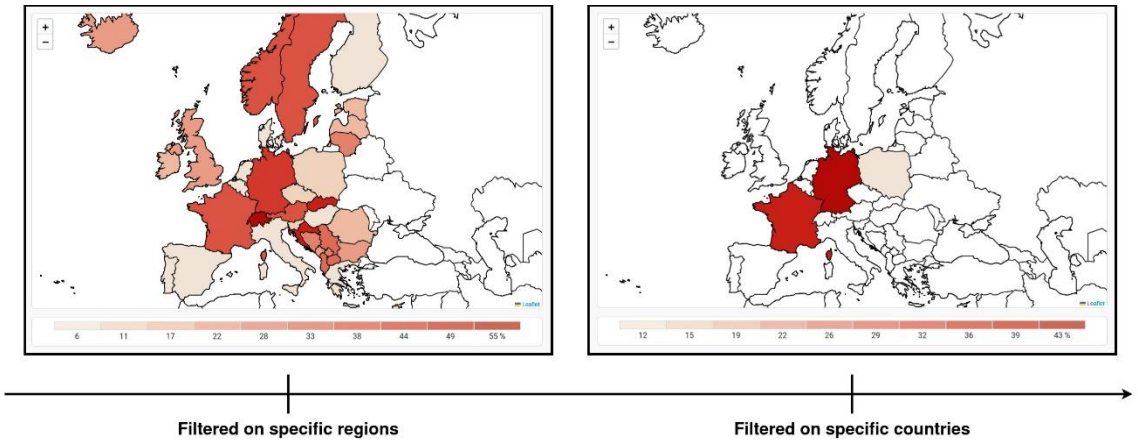


Figure 4 : Filtering options showing emissions data by region (left: Western and Central Europe) and by country (right: France, Germany, and Poland)

3.3.2 Graph view

The **Graph** component displays emission data as bar charts, providing a clear comparison of emission factors and their uncertainties. Users can group data by country or region using the tabs above the **charts**, and tooltips reveal precise values for each bar.

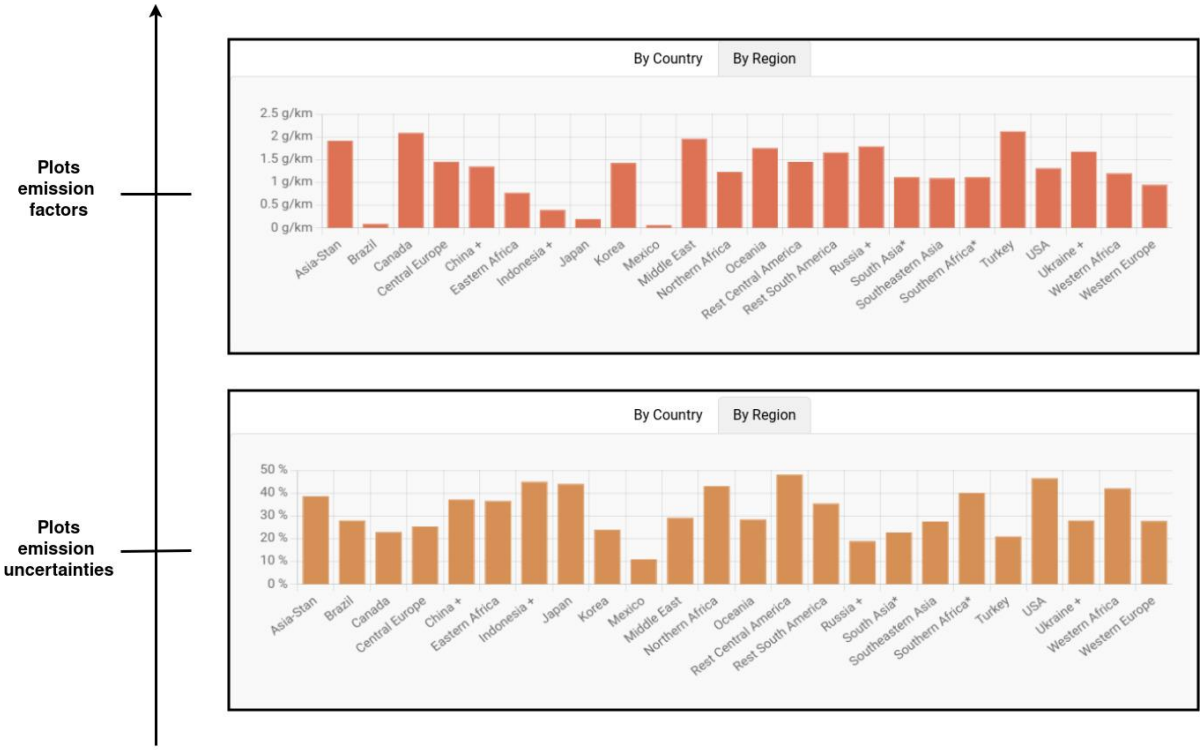
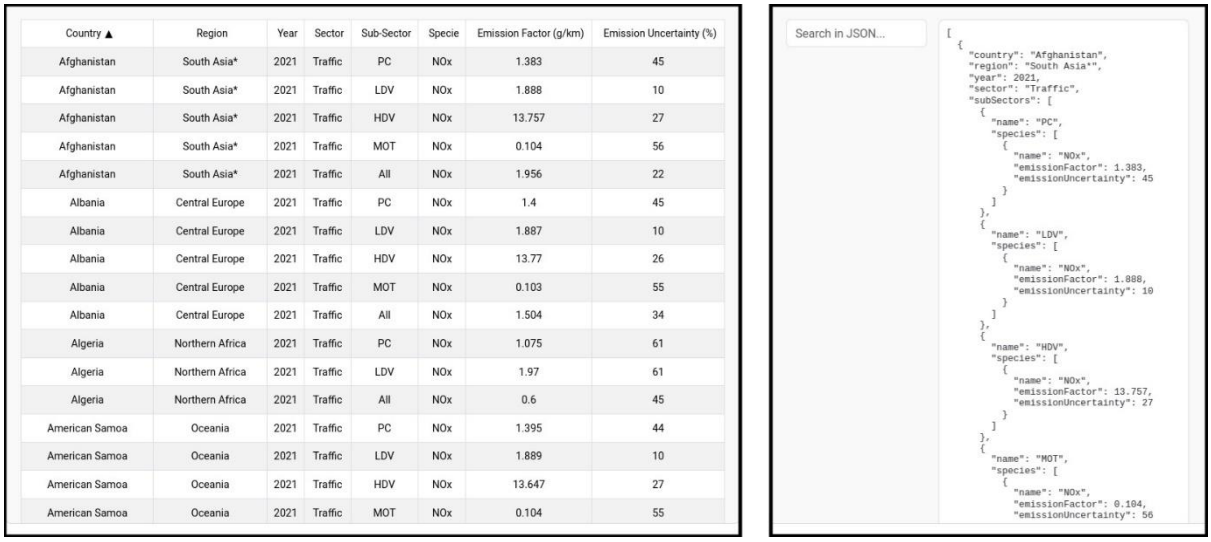


Figure 5 : Bar charts comparing emission factors (top) and uncertainties (bottom) grouping by region

3.3.3 Download view



Country ▲	Region	Year	Sector	Sub-Sector	Specie	Emission Factor (g/km)	Emission Uncertainty (%)
Afghanistan	South Asia*	2021	Traffic	PC	NOx	1.383	45
Afghanistan	South Asia*	2021	Traffic	LDV	NOx	1.888	10
Afghanistan	South Asia*	2021	Traffic	HDV	NOx	13.757	27
Afghanistan	South Asia*	2021	Traffic	MOT	NOx	0.104	56
Afghanistan	South Asia*	2021	Traffic	All	NOx	1.956	22
Albania	Central Europe	2021	Traffic	PC	NOx	1.4	45
Albania	Central Europe	2021	Traffic	LDV	NOx	1.887	10
Albania	Central Europe	2021	Traffic	HDV	NOx	13.77	26
Albania	Central Europe	2021	Traffic	MOT	NOx	0.103	55
Albania	Central Europe	2021	Traffic	All	NOx	1.504	34
Algeria	Northern Africa	2021	Traffic	PC	NOx	1.075	61
Algeria	Northern Africa	2021	Traffic	LDV	NOx	1.97	61
Algeria	Northern Africa	2021	Traffic	All	NOx	0.6	45
American Samoa	Oceania	2021	Traffic	PC	NOx	1.395	44
American Samoa	Oceania	2021	Traffic	LDV	NOx	1.889	10
American Samoa	Oceania	2021	Traffic	HDV	NOx	13.647	27
American Samoa	Oceania	2021	Traffic	MOT	NOx	0.104	55

Figure 6 : Download component showing a table preview (left) and a JSON-like list (right) of filtered emission data, both available for download.

The **Download** component lets users preview and export emission data in **JSON** or **CSV** format. The table dynamically updates in real-time as users adjust parameters such as countries, regions, or sectors, ensuring the data reflects the latest selections. Two preview tabs are available: JSON for quick inspection, including a research bar, and CSV for an organized table view. The table includes sortable columns and displays the following fields: **Country**, **Region**, **Year**, **Sector**, **Sub-Sector**, **Specie**, **Emission Factor (g/km)**, and **Emission Uncertainty (%)**. In addition, users can download the filtered data in their preferred format for further analysis.

3.4 Example of usage

The example shown in Figure 7 demonstrates how a user can utilize the COCAU prototype to filter, analyse, and download emission data for a specific workflow.

- The user begins by selecting the sector **PC** from the selection panel. They focus on a specific part of Asia by filtering the regions **Asia-Stan**, **China+**, **South Asia***, and **Southeastern Asia**. Using the zoom functionality, they explore this area in detail on the **interactive map**, where emissions are displayed through a dynamic legend.
- Next, the user switches to the **Graph** component. Bar charts display the emission factors (g/km) and associated uncertainties (%) for the selected regions. This visualization allows for a clear comparison of trends across the filtered areas.

Figure 7 : Example use case demonstrating the COCAU prototype workflow

- Finally, the user moves to the **Download** component. They check the preview of the filtered data in the **CSV Preview** tab, which includes columns such as Country, Region, Year, Sector, Sub-Sector, Specie, Emission Factor (g/km), and Emission Uncertainty (%). The user then clicks the **Download CSV** button to download the corresponding data file directly to their computer

4 Comparison of publicly available global and regional emissions datasets

4.1 Methodology

As indicated in Section 3, the development of the tool is currently allowing to calculate online the uncertainties on the emissions from transportation linked to the uncertainties on emission factors. Until further developments can be made to this prototype, we have worked on an additional method to obtain the uncertainties on the emissions for NOx, CO, SO2 and OC, i.e. the species indicated in the CAMEO project contract.

We have started a systematic comparison of emission inventories at the global and regional scales, using only publicly available datasets. This comparison will allow to define the minimum and maximum values of the emissions for each region, species and sector. As most of the global inventories are not independent of each other because all of them use data from the other ones, standard statistical analysis such as the calculation of the standard deviation would not be meaningful. This is why we are proposing the calculation of the ratio of the maximum to minimum values of the emissions as an alternative way of estimating uncertainties.

4.2 List of global and regional inventories included in the calculation of minimum and maximum values

We have used the inventories indicated in Table 2 (global datasets) and Table 3 (Regional datasets). It should be noted that no detailed information is available for these global and regional inventories on the emission factors and activity data used to calculate the emissions, and none of them is either provided with information on their uncertainties. The websites providing the datasets included in Table 2 and 3 are given in Annex 3.

Acronym	Versions	Institute	Period	Spatial Resolution
CAMS-GLOB-ANT	6.2 5.3	MPI-M and CNRS CNRS	2000-2025 2020-2024	0.1x0.1
EDGAR	8 6 5	JRC JRC JRC	1970-2022 1970-2018 1970-2015	0.1x0.1
HTAP	3	JRC	2000-2018	0.1x0.1
CEDS	2024 2021	PNNL and Univ. Maryland, USA	1750-2022 1750-2019	Not gridded 0.5x0.5
ECLIPSE	6	IIASA	1990-2050 (every 5 years)	0.5x0.5
LRTAP		IIASA	1990-2050 (every 5 years)	0.5x0.5
MACCity		CNRS	1960-2020	0.5x0.5

Table 2: list of the global datasets included in the comparison of inventories

Acronym	Versions	Institute	Period	Spatial Resolution
Europe				
CAMS-REG	7.1 6.1 5.1	TNO TNO TNO	2021 2019-2020 2000-2018	0.05x0.1
USA				
EPA	2024	EPA	1970-2023	Not gridded
China				
MEIC	1.4	Tsinghua University	2000-2020	0.25x0.25
MIX	2	Tsinghua Univ./ NOAA	2010-2017	0.1x0.1
REAS	3	ACAP, Japan	1950-2015	0.25x0.25
India				
MIX	2	Tsinghua Univ./ NOAA	2010-2017	0.1x0.1
REAS	3	ACAP, Japan	1950-2015	0.25x0.25
Latin America				
PAPILA	2	University of Chile	2014-2020	0.1x0.1

Table 3: list of the regional datasets included in the comparison of emission datasets

As can be seen with Table 3, we have not used regional datasets for Africa. One dataset is available, called DACCIWA, developed by a group in Ivory Coast. The dataset is currently being checked and evaluated. This evaluation work should be completed by January/February 2025, i.e. too late to be included in this report. If users of the uncertainties are interested in updated values for Africa, an update of the report could be done in the Spring of 2025 (at no cost for the project).

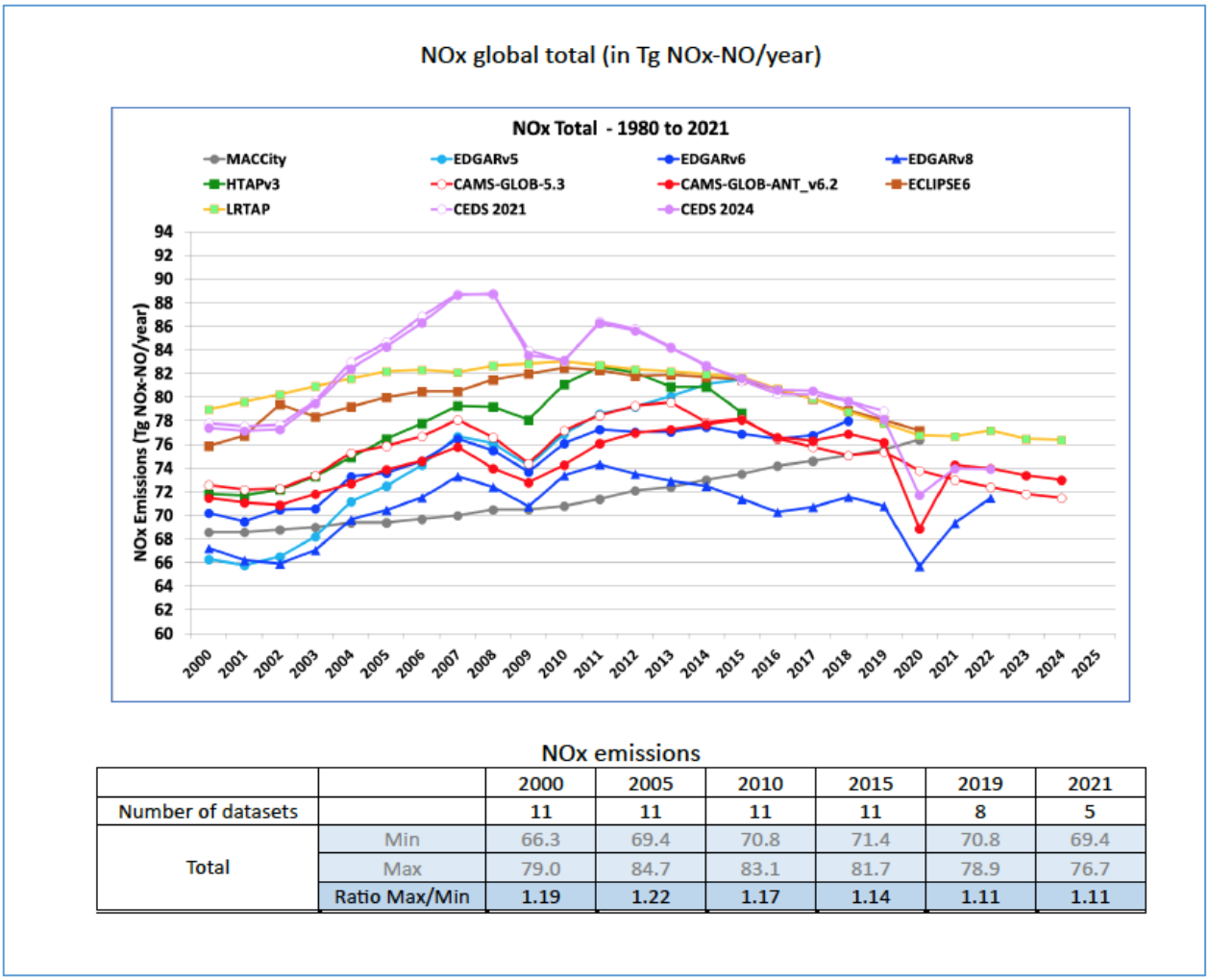
4.3 Uncertainty determined by the maximum to minimum ratios

The values of the maximum/minimum ratios are presented as shown in Figure 8. For each region and species, a one-page PDF document is available, which displays a plot of all the totals emitted from 2000 to 2024 from all the datasets available, followed by a table giving for the years 2000, 2005, 2010, 2015, 2019 and 2021 the number of datasets available, the minimum and maximum values and the corresponding maximum/minimum ratio. The year 2020 has not been used here to display the results, as some inventories take into account Covid-19 adjustments factors, and some do not. The example in Figure 8 shows the values for the NOx global totals.

With 24 regions plus the global totals and four chemical species (NOx, CO, SO2 and OC), the number of tables is equal to 100. It is therefore impossible to display all the results in a report. Only a few results will be shown here. All the results similar to the one displayed in Figure 8 have been included in a google drive, at: https://drive.google.com/drive/folders/1TrHHQIM2HSViO89AHIj8ZzFqK9YQ6U3V?usp=drive_link . These data will be put in a public repository such as zenodo at the end of the project.

Note that, when using the tables for the NOx species, users are invited to check the units used, which are in this report in Tg NOx as NO, as they are in the ECCAD database (Emissions

of atmospheric Compounds and Compilation of Ancillary Data, ECCAD: eccad.sedoo.fr), the database where most of the inventories used in this section are available.
The values for Mexico, Brazil and the rest of South America have been calculated by removing the emissions from agriculture waste burning and from wildfires: the PAPILA regional dataset includes both agriculture waste burning and wildfires in a single sector. To make the comparisons meaningful, it was decided to calculate the totals without agriculture waste burning and wildfires for these three regions.



NOx emissions

		2000	2005	2010	2015	2019	2021
Number of datasets		11	11	11	11	8	5
Total	Min	66.3	69.4	70.8	71.4	70.8	69.4
	Max	79.0	84.7	83.1	81.7	78.9	76.7
	Ratio Max/Min	1.19	1.22	1.17	1.14	1.11	1.11

Figure 8: Example of the one-pager PDF file providing the results of the global totals for NOx

Table 4 shows the results in 2015 and 2021 for the global totals and for the regions described in Section 2.2.3. In this table, the results are given as the percentage difference between the maximum and minimum values. We show in Table 5 the results for 2015, which is one the year for which the largest number of inventories is available, and the results are therefore more representative of the uncertainties in the past 10 years. We also indicate the values for 2021, which is the most recent years with at least 5inventories available.

In order to better represent the countries/regions with the smallest maximum/minimum ratio, the following colours have been used in Tables 4 and 5:

- Percentage difference below 25% : green
- Percentage difference between 26 and 50%: blue
- Percentage difference between 51 and 100%: yellow
- Percentage difference between 101 and 200% : orange
- Percentage difference above 201%: pink

Results for 2021

2021				
	NOx	CO	SO2	OC
Global scale				
Global Total	11%	76%	76%	18%
Regions and countries				
Europe				
Western Europe	38%	15%	162%	74%
Central Europe	30%	26%	192%	80%
Americas				
USA	60%	78%	206%	127%
Canada	29%	76%	64%	203%
Mexico	61%	126%	551%	224%
Rest Central America	28%	77%	114%	98%
Brazil	17%	74%	72%	187%
Rest South America	64%	176%	63%	172%
Africa				
Northern Africa	153%	710%	48%	1028%
Western Africa	64%	33%	88%	58%
Eastern Africa	98%	77%	145%	150%
Southern Africa	12%	41%	54%	100%
Russia and others				
Russia	27%	89%	133%	183%
Ukraine	26%	90%	159%	79%
Turkey	21%	165%	203%	99%
Asia				
China	7%	18%	176%	34%
India	21%	38%	47%	48%
Asia-Stan	100%	119%	111%	194%
Middle East	38%	244%	101%	449%
Korea	80%	74%	154%	200%
South-East Asia	38%	68%	79%	41%
Indonesia	131%	191%	96%	103%
Japan	30%	51%	139%	282%
Oceania	13%	33%	42%	98%

Table 4: Uncertainties on the emissions determined by the maximum/minimum ratios in 2021.

Results for 2015

2015				
	NOx	CO	SO2	OC
Global scale				
Global Total	14%	36%	48%	23%
Regions and countries				
Europe				
Western Europe	42%	35%	116%	111%
Central Europe	22%	9%	54%	162%
Americas				
USA	42%	85%	180%	167%
Canada	26%	90%	73%	269%
Mexico	111%	117%	425%	200%
Rest Central America	48%	91%	151%	107%
Brazil	82%	91%	118%	213%
Rest South America	61%	200%	101%	231%
Africa				
Northern Africa	137%	632%	77%	1049%
Western Africa	69%	36%	344%	84%
Eastern Africa	119%	126%	159%	174%
Southern Africa	17%	80%	33%	122%
Russia and others				
Russia	67%	71%	129%	209%
Ukraine	44%	65%	56%	104%
Turkey	73%	129%	140%	340%
Asia and Oceania				
China	15%	45%	99%	59%
India	28%	105%	53%	65%
Asia-Stan	88%	141%	90%	221%
Middle East	44%	555%	101%	428%
Korea	61%	238%	353%	421%
South-East Asia	117%	118%	90%	185%
Indonesia	148%	141%	100%	136%
Japan	99%	128%	248%	611%
Oceania	21%	16%	70%	90%

Table 5: Uncertainties on the emissions determined by the maximum/minimum ratios in 2015.

Except for the global totals, very large differences are found for all species and regions. As none of the inventory provides detailed information on the data used to calculate the emissions, it is currently not possible to identify the reasons for the large discrepancies.

The species for which the largest differences are found are SO2 and OC. For SO2, these large differences might be due to a lack of updates in several inventories: measures have been taken in many countries in the recent years to limit the emissions of SO2, but some inventories might have not included these features in their calculations. For OC, the differences are even larger than for SO2, which might be related to differences in the definition of OC and in the sectors considered, as well to large differences in the values of the emission factors.

For NOx, the differences are generally smaller: this could be due to the fact that more emphasis has been put on the quantification of the emissions of this specie in the past few years.

5 Conclusions and future work

The goals for the work planned within WP5 of CAMEO have been reached, knowing that CNRS had a budget covering a maximum of 12 person-months in the CAMEO project.

We have developed the online COCAU tool, which allows for now the calculation of the uncertainties of the NOx emissions from traffic, based on the uncertainties on emission factors. If more funding can be found to develop further the COCAU tool, we will:

- Improve the calculation of the uncertainties by taking into account not only the uncertainties on the emission factors, but also on activity data. It should be noted that publicly available activity data for traffic are not easily accessible.
- Add the calculation of the uncertainties of traffic emissions for more chemical species, such as CO, NMVOCs, BC and OC.
- Add the calculation of the uncertainties on the emissions from other sectors: the first sector to be considered will be the energy sector, followed by the industry, residential, solvents, waste and agriculture sectors.

The systematic comparisons of the emissions will be continued and be updated (at no cost for the project) by including more species (for example NMVOCs, NH3 and BC) and adding new inventories, such as:

- The DACCIWA2 inventory for Africa, which is under evaluation, as mentioned above
- The new AEIM inventory of pollutants for India, which should be made available to our group at the beginning of 2025
- The BRAVES emissions from transportation in Brazil which should also be available at the beginning of 2025
- The new global inventory called GEMS developed by the Peking University (PKU) and the Southern University of Science and Technology (SUSTECH) in China. We should be able to use this dataset in the Spring of 2025.

More information on the uncertainties using the maximum/minimum ratio of the emissions could be obtained by doing these calculations at the sector level, i.e. transportation, energy, industry, residential, solvents and agriculture. Similar calculations could also be done for other species. If CAMEO partners are interested in such calculations, some of them could be done (at no cost for the project), but it should be noted that the calculations and analysis of the results for one species for all the regions take approximately one month.

Annex 1

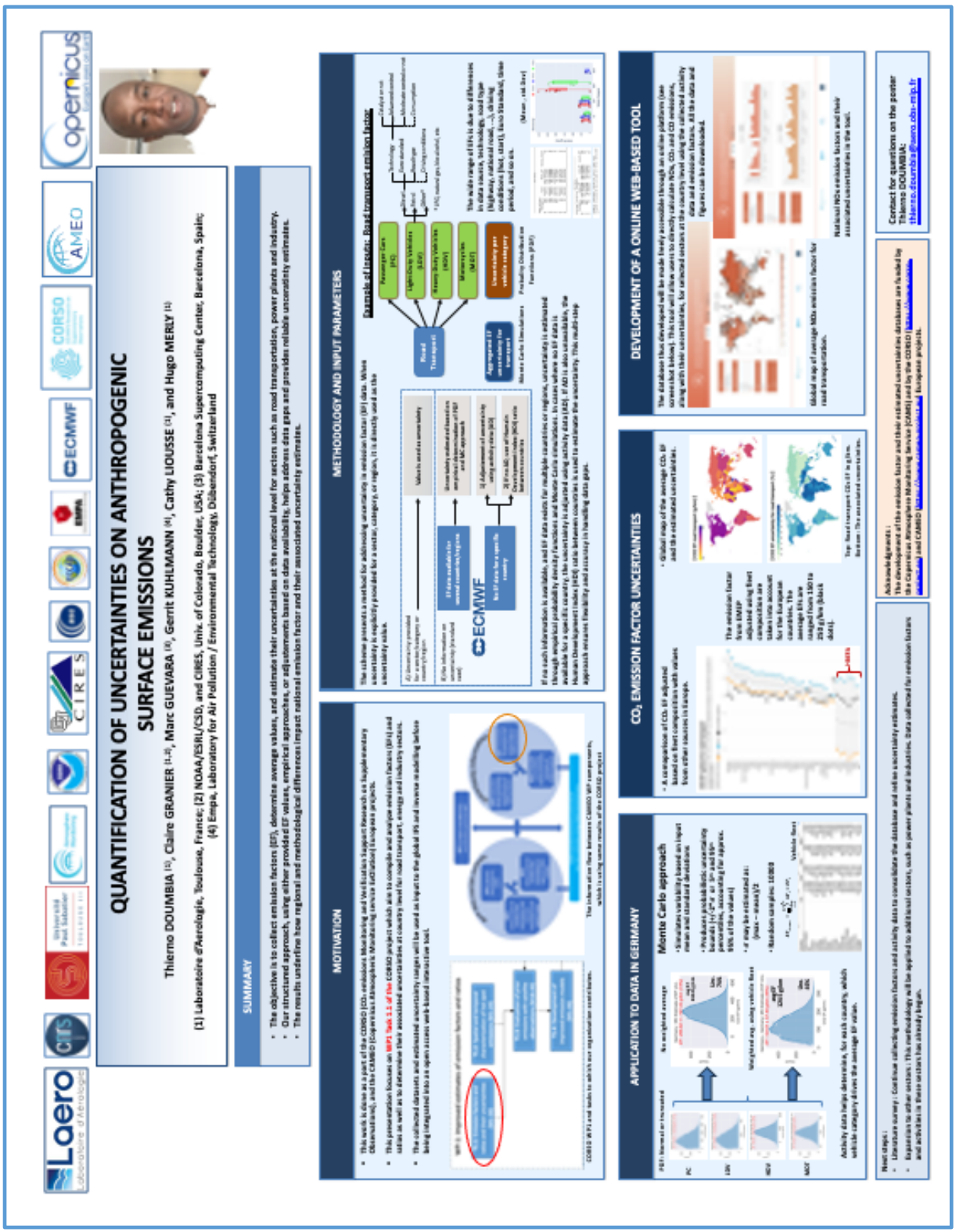
Region	Countries included in the region	Remarks
Canada	Canada	
USA	USA + Saint Pierre and Miquelon	
Mexico	Mexico	
Rest of Central America	Anguilla + Antigua and Barbuda + Aruba + Bahamas + Belize + Bermuda + Cayman + Costa Rica + Cuba + Dominica + Dominican Rep. + El Salvador + Grenada + Guadeloupe + Guatemala + Haiti + Honduras + Jamaica + Martinique + Montserrat + Netherland Antilles + Nicaragua + Panama + Puerto Rico + Saint Kitts and Nevis + Saint Lucia + Saint Vincent + Grenadines + Trinidad + Tobago+ Turks and Caicos + Virgin Islands	
Brazil	Brazil	
Rest of South America	Argentina + Bolivia + Bouvet + Chile + Colombia + Ecuador + Falklands/Malvinas + French Guiana + Guyana + Paraguay + Peru + South Georgia + Suriname + Uruguay + Venezuela	
Northern Africa	Algeria + Egypt + Morocco + Tunisia + Western Sahara	
Western Africa	Benin + Burkina Faso + Cape Verde + Central African Republic + Chad + Congo + Democratic Republic of Congo + Ivory Coast + Equatorial Guinea + Gabon + Gambia + Ghana + Guinea + Guinea-Bissau + Liberia + Mali + Mauritania + Niger + Nigeria + Saint Helena + Sao Tome and Principe + Senegal + Sierra Leone + Togo	
Eastern Africa	Burundi + Comoros + Djibouti + Eritrea + Ethiopia + Kenya + Madagascar + Mauritius + Mayotte + Reunion + Rwanda + Seychelles + Somalia + Uganda	
Southern Africa	Angola + Botswana + Lesotho + Malawi + Mozambique + Namibia + South Africa + Swaziland + Tanzania + Zambia + Zimbabwe	
Western Europe	Andorra + Austria + Belgium + Denmark + Faroe Islands + Finland + France + Germany + Gibraltar + Greece + Vatican + Iceland + Ireland + Italy + Liechtenstein + Luxemburg + Malta + Monaco + Netherlands + Norway + Portugal + San Marino + Spain + Svalbard + Sweden + Switzerland + United Kingdom	The calculation of uncertainties for most individual countries are also included in the online tool
Central Europe	Albania + Bosnia and Herzegovina + Bulgaria + Croatia + Cyprus + Czech Republic + Estonia + Hungary + Latvia + Lithuania + Macedonia + Malta + Poland + Romania + Slovakia + Slovenia + Yugoslavia	The calculation of uncertainties for most individual countries are also included in the online tool
Turkey	Turkey	

Region	Countries included in the region	Remarks
Ukraine	Belarus + Moldova + Ukraine	
Asia-Stan	Kazakhstan + Kyrgyzstan + Tajikistan + Turkmenistan + Uzbekistan	
Russia		
Middle East	Bahrain + Iran + Iraq + Israel + Jordan + Kuwait + Lebanon + Oman + Qatar + Saudi Arabia + United Arab Emirates + Yemen	
India	India + Bangladesh + Pakistan + Afghanistan + Nepal + Bhutan + Maldives + Sri Lanka	In the min/max calculations, the "India" region only includes the country of India
Korea	South Korea + North Korea	
China	China + Hong-Kong + Macau + Taiwan + Mongolia	In the min/max calculations, the "China" region does not include Mongolia
South-East Asia	Brunei + Cambodia + Laos + Malaysia + Myanmar + Philippines + Singapore + Thailand + Vietnam	
Indonesia	Timor + Indonesia + Papua New Guinea	
Japan	Japan	
Oceania	American Samoa + Austria + Christmas Island + Cocos + Cook + Fiji + French Polynesia + Guam + Kiribati + Micronesia + Nauru + New Caledonia + New Zealand + Niue + Norfolk + Mariana islands + Palau + Pitcairn + Samoa + Solomon + Tokelau + Tonga + Tuvalu + Vanuatu + Wallis and Futuna	

Table 1: Definition of the countries and regions considered in this report.

Annex 2

Poster presented at the 2024 AGU conference by Doumbia et al.



Annex 3

List of the websites corresponding to the inventories shown in Tables 2 and 3

CAMS-GLOB-ANT: eccad.sedoo.fr

EDGAR: https://edgar.jrc.ec.europa.eu/

HTAP: https://edgar.jrc.ec.europa.eu/

CEDS: https://zenodo.org/records/12803197

and https://github.com/JGCRI/CEDS/wiki/Release-Notes

ECLIPSE: https://iiasa.ac.at/models-tools-data/global-emission-fields-of-air-pollutants-and-ghgs

LRTAP: https://zenodo.org/records/10366132

MACCITY: eccad.sedoo.fr

CAMS-REG: eccad.sedoo.fr

EPA: https://www.epa.gov/air-emissions-inventories/air-pollutant-emissions-trends-data

MEIC: meicmodel.org

MIX: https://csl.noaa.gov/groups/csl4/modeldata/data/Li2023/

REAS: https://www.nies.go.jp/REAS/

PAPILA: https://zenodo.org/records/12944491

Document History

Version	Author(s)	Date	Changes
1.0	Hugo Merly, Claire Granier	December 6, 2024	Initial version
2.0	Hugo Merly, Claire Granier	December 31, 2024	Table 4 and 5 finalized
2.2	Hugo Merly, Claire Granier	Jan 2025	Minor revisions to text as a result of reviews

Internal Review History

Internal Reviewers	Date	Comments
Marc Guevara (BSC), FMI	Jan 2025	